Written examination in

PPU080 – Advanced Computer Aided Design

Date: 2018-11-01, 8.30 – 12:30

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Department: Industrial and Materials Science

Solution to the exam: On the course home page the day after the exam.
Preliminary results: On the course home page before 2018-11-20

Inspection of your exam result (at Lars Lindkvists office):

- 2018-11-21, 12.00-13.00
- 2018-11-22, 12.00-13.00

Aids

None.

The examination contains 5 tasks, each worth 10 points.
Grades:

< 20 points: Fail
20-29 points: Grade 3
30-39 points: Grade 4
40-50 points: Grade 5

Do not treat more than one task on each page.

1. Geometry modeling

a) Describe the following three types of solid models, mention some advantages or disadvantages for each (6p)
   - Decomposition models
   - Constructive models
   - Boundary representation

b) Curves used in geometry modeling can be of different order. What are the advantages and disadvantages of higher order curves? (2p)

c) What is a digital mockup (DMU) and for what is it used? (2p)

Answers

a)

Decomposition models:

- Can be made of:
  - Voxels: the solid is composed of a number of cubes
  - Cell based: the solid is built up by polygons
- It is an approximate model and requires a lot of memory for high precision.
- It is suitable for different types of calculations

Constructive models:

- Solid models are created by manipulating primitives with Boolean operators.
- It is hard to handle general surfaces
- It is very compact (do not require a lot of memory)

Boundary representation:

- The solid is defined with points, curves and surfaces plus a definition of what is inside the model
- Uses graphical methods e.g. sweep and rotate
- Can use parametric surfaces
- Can use Boolean methods

b)

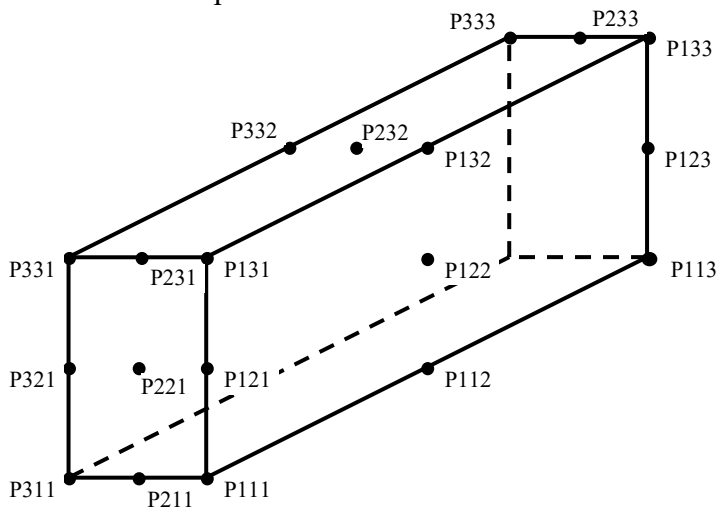
- Advantage: increased precision
- Disadvantages: risk for corrupt curves, increased calculation time

c)

- A special type of component based assembly model developed to be able handle large assemblies (> 1000 parts) from different CAD-systems
- Can be used for e.g. packaging studies and assembly simulation but not for e.g. calculation of mass etc.

2. Geometry assurance

a) Describe how a 3-2-1 locating scheme works (4p)
b) Define a 3-2-1 locating scheme for the box in the figure (6p)
- Use the points in the figure (P111-P333, located on the three visible surfaces)
- Try to make it as robust as possible
- **Motivate** your selection of points



Answers

a)
- Six DOF are locked by six points
- Primary points A1, A2 and A3 defines a plane and locks the geometry in space in two rotations and one translation: TZ, RX, RY
- Secondary points, B1 and B2, defines a line and locks the geometry in space in one rotation and one translation: TY, RZ
- Tetriary point C1 locks the geometry in space in one translation: TX

b)
A number of different solutions with almost the same robustness exist. This is one solution.
- Primary points A1, A2 and A3:
  - Points: P131, P133 and P112
  - This maximizes the area of the triangle defined by the points
  - Also e.g. P131, P133 and P113 would give the same area but in that case the corner P111 will be less robust
- Secondary points B1 and B2
  - Points P231 and P233
  - This maximizes the length of the line defined by the two points
  - (Also other selections gives the same length but this is the optimal one)
- Tertiary point C1
  - Point P221
  - (Any point on the same surface is OK but this is the optimal one)

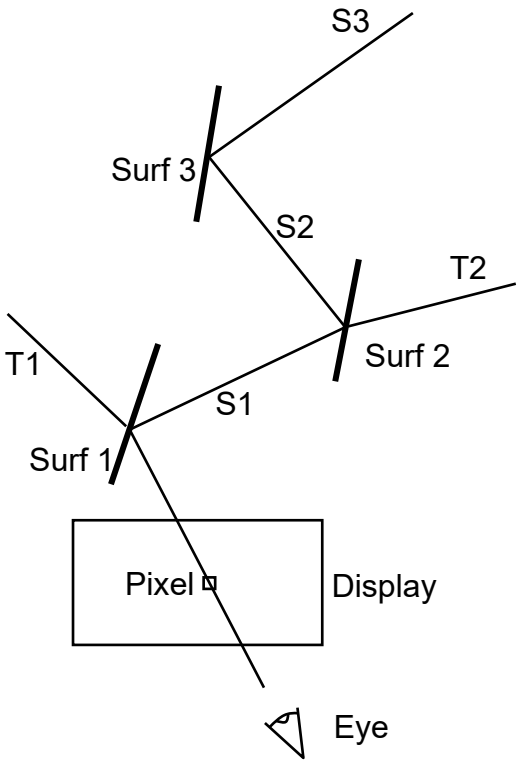
3. Computer graphics and virtual reality

Ray-Tracing and Radiosity are two different methods for advanced 3D computer graphics rendering.

c) Describe how these methods work. (4p)
d) Mention two advantages and two disadvantages of each of the two methods. (2p)
e) Three different types of coordinate systems are used in virtual reality models (and also in CAD models). Specify these and what they are used for. (4p)

Answers

a)



Ray-tracing

- Follow light rays from the observer, one for each pixel
- Calculate how the ray is mirrored and refracted (if the object is transparent) when it hits surfaces in the model, and save the way in a tree graph
- Calculate the intensity at the initial points with illumination models
- Use the tree to calculate the intensities at each pixel
- Handles automatically shadows, hidden surfaces and clipping

Radiosity

- Based on the effect that light sources and surfaces are emitting light
- Is done by iterating the emission of light
- In the first step only surfaces with direct light are visible
- In the next step these surfaces emits light to other surfaces
- This is repeated until the result is satisfactory

b) (two each of)

Ray-tracing

- Advantages
  - Good at transparent objects
  - Handles specular reflection well
  - Good at point light sources

- Disadvantages
    - Unnaturally sharp shadows
    - Bad at diffuse reflection
    - Not good at global light sources
    - Slow

Radiosity

- Advantages
    - Good at diffuse reflection
    - Gives realistic shadows
    - Good at global light sources
- Disadvantages
    - Not good at specular reflection
    - Not good for transparent objects
    - Not good at point light sources
    - Slow

c)

1. World coordinate system (w)
    - Only one in each model
    - The position of other objects are related to this
2. Object coordinate system (o)
    - One coordinate system per object in the model
    - Positions the object relative to the world coordinate system or relative to a superseding object
3. The coordinate system of the observer (Virtual Observer)
    - Makes it possible to travel around in the model

4. Miscellaneous

a) Mention the five basic needs of a PDM system. (5p)
b) Geometry models, created in a CAD-system, are used by a number of different functions (departments etc.) within the product development process. Describe some problems related to this. (2p)
c) Mention three reasons for the increased industrial need for IT support for product development (3p)

Answers

a)

- Capture information at the source
- Organize information
- Distribute the information – when, where, what, to whom
- Search, re-use and present information
- Secure storage of information over a long time

b)

- Different functions uses different software requiring different file formats: problem with file conversion
- Problem with access to the right models

c)

- Shorter lead-times and product lifecycles
- Increased complexity: variants, functions, components etc.
- Collaborative product development

5. Miscellaneous

a) Describe how the Z-buffer algorithm for depth sorting of objects drawn on a computer screen works. (4p)
b) What characterizes a geometrically robust assembly concept? (2p)
c) What are the advantages of a geometrically robust assembly concept? (2p)
d) Mention two advantages of using off-line programming. (2p)

Answers

a)

- Initiate video memory and a Z-buffer for each pixel on the screen
- $depth[x, y] = \infty, \qquad refresh[x, y] = I_{background}$
- Polygons are rendered in an arbitrary sequence
- For each pixel: check if the z-coordinate of the current polygon is less than the stored one (use the plane equation for the polygon)

  $Ax + By + Cz + D = 0\,,\ z_{x,y} = \dfrac{-(Ax + By + D)}{C}$
- In that case the video memory is updated for the pixel

  $z_{x,y} < depth[x, y] \Rightarrow depth[x, y] = z_{x,y}\,, \quad refresh[x, y] = I_{surf}$
- When all polygons are checked the screen is updated with the color closest to the observer

b)

A geometrically robust design is a design that allows manufacturing and assembly variation without jeopardizing function or aesthetics.

c)

- Easier process adjustment and tuning
- Shorter start and ramp-up times
- Global production with high and equal quality level

d)

- Avoid costly mistakes with real machines
- Faster and more efficient programming
- Possibility to make new programs without stopping the production